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SUMULTANEOUS LINE-OF-SIGHT TERRAIN EFFECTS ON REMOTED WEAPON SYSTEMS

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FOREWORD

This analysis is based upon experimental data gathered by the U.S. Army Combat Developments Experimentation Center, Fort Ord, California during the TETAM Experiment 11.8 Phase I experimentation. The analysis was performed by the Directorate of Combat Operations Analysis (COA) of the U.S. Army Combined Arms Combat Developments Activity, Combined Arms Center, Fort Leavenworth, Kansas in partial support of the Hellfire Cost and Operational Effectiveness Study.

The individuals having major responsibility in the analysis effort are Dr. L. G. Pfortmiller of the Methodology and Quality Assurance Branch and Mr. Jack Low, Jr. of the Test Planning and Analysis Branch within the Directorate of Combat Operations Analysis.

ABSTRACT

This report contains an analysis of the impact of terrain on the dual simultaneous line-of-sight (LOS) requirements of a remote target designation weapon system when both parties are operating at surface or near surface terrain environments. The analysis uses the Phase I TETAM intervisibility data measured for ground antitank missile positions on terrain located within the Hunter-Liggett Military Reservation. Study results include comparisons of autonomous single sites with remoted systems for quantities such as area LOS probabilities, duration of moving target intervisibility, and distributions of multiple target intervisibility. An estimate of the degradation of the remoted systems relative to the autonomous mode systems is also displayed.

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Section I. BACKGROUND AND ANALYSIS METHODOLOGY

1. INTRODUCTION AND BACKGROUND.

a. The complex interaction of terrain, tactics, and weapon system technology has long been the subject of discussion and analysis, particularly in the field of tank/antitank weapons. Current development of antitank missile technology points toward the feasibility of weapon systems capable of operating at ranges in excess of all but a few of the line-of-sight distances encountered in surface-to-surface ground engagements. This range capability, however, cannot be achieved without a substantial increase in the weight, size, and per unit cost of the weapon system. This increased cost, together with increasing personnel costs, when considered in light of a cost-constrained budget, points directly toward a reduced weapon density on the battlefield. Thus, the influences of terrain limitations on the frequency of use of the additional range capability, and the accompanying density versus rate-of-fire tradeoffs involved, take on additional importance.

b. The advent of the attack helicopter, coupled with the remote target designation capability afforded by the semiactive laser terminal homing concept, provides a specific example of the above process. In the effectiveness evaluation of such a system, an understanding of the terrain limitations accompanying the operational employment is paramount. This report represents an effort to examine some of these terrain effects through a limited analysis of the TETAM Phase IA intervisibility data base. 1/

2. PURPOSE. The purpose of this analysis is to examine terrain intervisibility effects on selected ground or near surface weapon systems whose performance is dependent upon target handoff and/or remote designation capabilities. Whereas considerable work has been expended to study the interaction of the terrain with the autonomous weapon system versus target complex, 2, 3, 4, 5, 6, 7/ much less effort has been expended studying similar effects for remoted weapon systems such as the semiactive laser terminal homing concept characterized by the attack helicopter Hellfire laser missile with remoted target designation. Specifically, one of the terrain-sensitive requirements associated with the employment of the Hellfire/remote designation system in the direct fire mode is the necessity for both the designator and the launch vehicle to have simultaneous line-of-sight to the same target.

3. OBJECTIVE. The primary objective is to estimate the impact of the terrain on the dual simultaneous line-of-sight (LOS) condition required for the employment of the remote direct fire mode of the Hellfire weapon system. Of additional interest is the different manner in which the terrain affects an autonomous system that can independently engage as contrasted with a remoted two-party system that requires command, control,

communication, and coordination to effect an engagement. Specific questions of concern addressed by the analysis are as follows:

a. How do the durations of LOS to targets (intervisible path segments) for autonomous mode systems compare with durations of simultaneous LOS to the target for remoted systems?

b. How does overall LOS to the target complex for autonomous mode systems compare to that expected for the remoted systems?

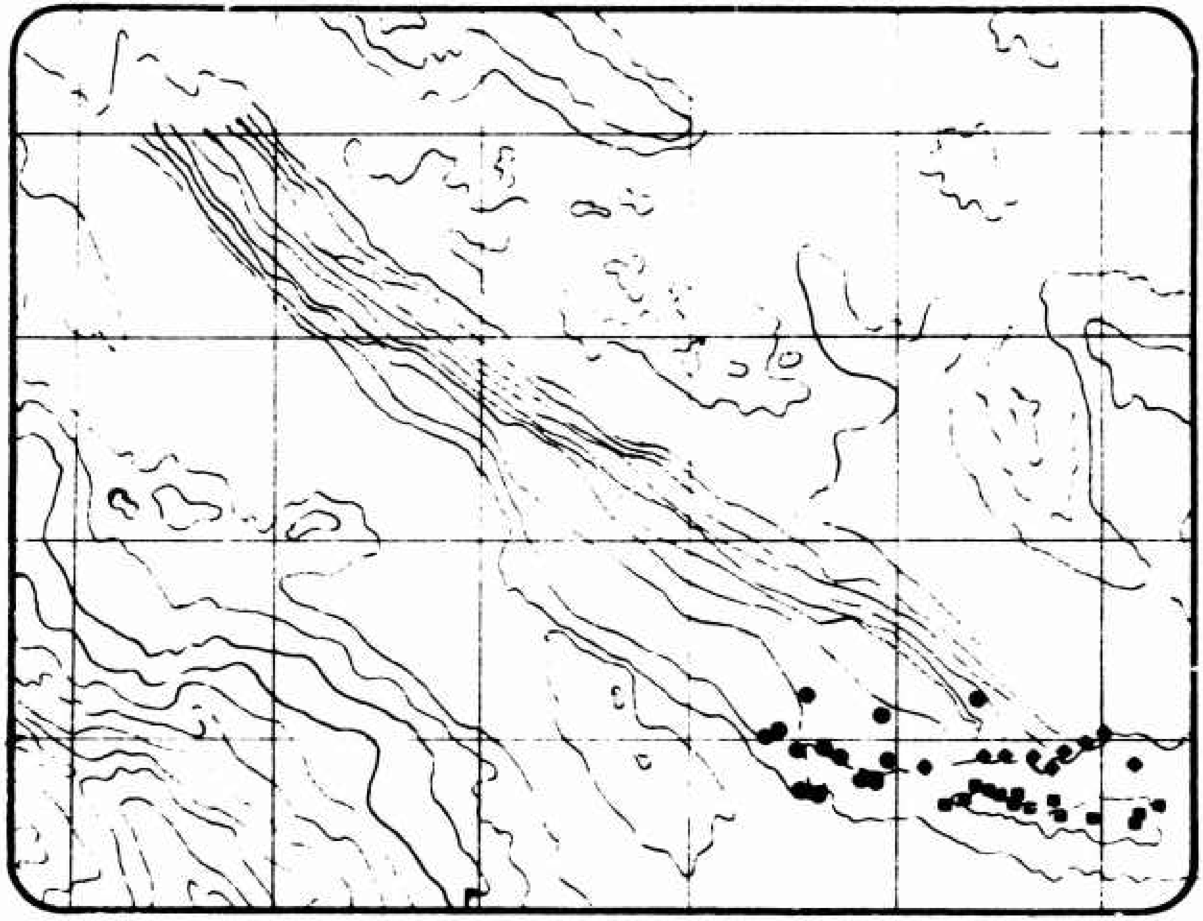
c. How does the density of multiple target intervisibility for an autonomous mode system compare to that expected for the remoted system?

4. SCOPE AND LIMITATIONS. The terrain intervisibility data used in this analysis were collected in the CDEC 11.8 field experiment, Tactical Effectiveness Testing of Antitank Missiles (TETAM) Phase IA. This analysis has been limited to an examination of the terrain site at Hunter-Liggett Military Reservation known as site ALPHA. A brief examination of site BRAVO revealed that engagement opportunities at ranges beyond 3000 meters are rare and that there were few suitable defensive positions that could provide masks for an AH or Scout designator. Although these two observations by themselves are indicative of limited occurrence of long-range engagement opportunities, the analysis was purposely restricted to the site ALPHA terrain to examine intervisibility effects in a terrain environment that is much more open than normally encountered. The TETAM Phase I terrain data for the two Fort Lewis sites and the 12 sites in West Germany, although available, have not been completely analyzed. Preliminary work, however, suggests that site ALPHA offers as many long range intervisibility opportunities as any of the other available sites.

5. DESCRIPTION OF THE TETAM PHASE I DATA. Familiarity with the procedure used to collect the TETAM intervisibility data is critical to an appreciation of the analysis.

a. Figure I-1 is a map of the portion of HLMR showing site ALPHA with the 10 tank trails and 36 defensive positions. The 10 tank trails were laid out to represent tank approach routes toward the defensive site positions. Each trail was marked every 25 meters. At each of the defensive site positions wooden panels representing either a TOW, DRAGON, or Shillelagh missile system position were erected.

b. Line-of-sight or intervisibility readings were then recorded from each marked position of all the trails to each wooden panel. Data collectors noted which of the panels they could see and the reason for partial obscuration of any panel. The basic intervisibility data consist of the location of each tank trail 25-meter point and each defensive site. Thus, a data pair for each defensive site and tank trail 25-meter point is created, which records the intervisibility status. From these data



• = Category I ♦ = Category II ● = Category III

(see page 6 for definition)

Figure I-1 - TETAM terrain site ALPHA at Hunter-Liggett Military Reservation with rapid approach tank trails and defensive sites

pairs the length of intervisibility segments and the range of initiation can be derived. For a terrain site such as site ALPHA with tank trails approaching 5 kilometers in length, a complete data set consists of approximately 7200 data pairs (36 defensive sites x 10 trails x ~ 200 positions per trail).

6. ANALYSIS APPROACH. The basis of the approach used to analyze the TETAM data is illustrated schematically by the Venn diagram of figure I-2. In this diagram the set of all targets available is defined as the total number of 25-meter tank trail segments traversed within a fixed range band by all 10 tanks as they approach the defensive sites. The circular areas, S_1 and S_2, represent that subset of tank trail segments intervisible to each of two selected defensive sites. The intersection of the two circles (S_1 S_2) or the overlap region represents the subset of tank trail segments simultaneously intervisible to both defensive positions. The analysis focuses on comparisons between S_1 and $S_1 \cap S_2$.

a. Assumptions.

(1) The primary assumption in the analysis of the CDEC data is that the defensive sites located at the crest of the ridge at Site A (Category I in figure I-1) are approximately representative of the intervisibility conditions expected for helicopter popup positions immediately behind the ridge when using nap-of-the-earth (NOE) tactics. These ridgeline sites are at elevations nearly 60 meters above the approach tank trail routes. A visual inspection of these sites indicated that this approximation should be valid for purposes of the analysis. Hereafter, in the report these sites are referred to for convenience as AH launch positions.

(2) A second assumption is that the designator or remoted party of the weapon system would select sites analogous to the ground positions. Although the 36 defensive site positions were selected in the TETAM experiment for specific types of antitank missiles (i.e., TOW, Shillelagh, DRAGON), it is assumed that in general, similar site selection criteria would also apply to the remoted weapon system since the availability of target opportunities remains a principal concern.

(3) The tank trail positions shown in figure I-1 are those for the threat force using a rapid approach movement tactic. Since the TETAM experiment and CDEC analysis compared the intervisibility between this threat tactic and the cover and concealment approach tactic, and found no significant difference, only one set of data is used in this analysis. To examine the multiple target intervisibility effects, the targets were assumed to move in a correlated manner along the tank trails such that all targets were always the same number of 25-meter segments away from their starting point.

b. Grouping of Data. For comparative purposes and to assess the impact of range to target, and remoted weapon system geometry, the data were grouped into two range bands and into three weapon site categories

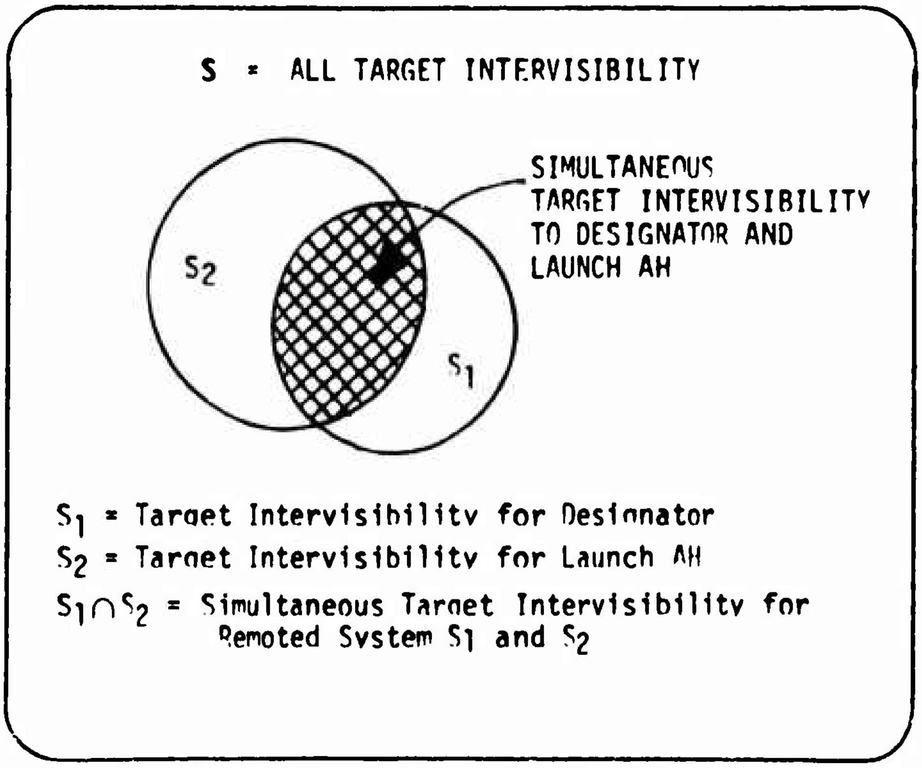


Figure I-2. Venn diagram illustrating simultaneous LOS requirements for remoted weapons systems

to represent the remote designator location relative to the terrain and weapon launch site. This grouping produced a total of six data combinations for analysis purposes.

(1) Range Bands. The two range bands chosen were for trails at 0 to 3000 meters and beyond 3000 meters (3000 to an average of 5500 meters). This choice was natural for site ALPHA as there exists a definite break in intervisibility conditions near 3000 meters, which is caused by a creek and the surrounding vegetation.

(2) Designator Categories. Figure I-1 illustrates the grouping of the 36 defensive sites into three categories as follows:

(a) Category I. These positions are very near the ridgeline overlooking the valley. These sites are assumed to be characteristic of both the launch AH and the aerial Scout designator popup positions. Fourteen positions were selected as shown on figure I-1.

(b) Category II. These positions were selected as representative ground designator positions located approximately 500 meters forward of the popup sites. The nine positions are shown on figure I-1.

(c) Category III. The third set of positions was chosen to represent designator locations for the designator ~1200 meters forward and slightly offset to the AH popup and launch sites. These positions accounted for the remaining 13 sites of the 36 defensive positions.

(3) Remoted Designator and Launch Aircraft Groupings. To represent the two-party remoted aerial weapon systems, each of the Category I or helicopter positions was paired with another Category I position to obtain a sample size of (14 x 13) = 182 remoted system pairs. These pairs were used to approximate the Hellfire laser system employing remote Scout aerial designation. To represent remoted systems typical of a ground designator and aerial launch aircraft, the Category I positions were combined with the Category II and III positions to obtain samples of (14 x 9) = 126 for ground designation positions ~500 meters forward of the launch sites and (14 x 13) = 182 for the ground designator positions ~1200 meters forward of the launch sites. A total remoted system sample size of 490 is thus obtained.

c. Analysis Procedure.

(1) The analysis procedure used a simple, direct, though time consuming counting and correlation process. Sequentially, within a given range band the 10 tank trail positions were checked from each autonomous site and from each paired data set of the remoted systems for intervisibility. From these data the number of intervisible trails and the duration of intervisibility were obtained and recorded. These data were used to calculate the area line-of-sight (LOS) probabilities, the distributions of intervisibility duration, the distribution of multiple

target intervisibility, and the expected degradation of opportunities for the remoted systems. These terms are defined in paragraph d below.

(2) In the IETAM experiment the intervisibility data were recorded on punched cards in the field and subsequently read onto a computer tape. A copy of this tape, containing all the data of Experiment 11.8, Phase IA, was the basis of this analysis. A major problem was the conversion of this tape, produced on CDEC's GE605 computer, to an acceptable form for the CDC 6500 at Fort Leavenworth. A set of analysis programs were developed and used to generate the data shown in the results. The program used to check the intervisibility for each remoted system site combination to each stake on the 10 paths at the various range intervals and designator categories required computer run times of about 8000 CPU seconds.

d. Definition of Terms.

(1) Area LOS Probability (P_{LOS} $(R,\Delta R,N_T,T^2)$. The term "area LOS probability" is used in this analysis to represent the ratio of the total number of 25-meter visible segments to the total number of 25-meter segments where these segments are summed across all defensive sites or pairs of sites for the remoted systems over all tank paths and over the entire length of the paths within the specified range band. It is a measure of the maximum number of opportunities available within a range band, $(R,\Delta R)$(also time interval) for a fixed number of advancing targets (N_T), and approach tactics and terrain conditions (T^2). It does not, however, distinguish between multiple target intervisibility and single target intervisibility or between different durations of exposure. Instead it can be thought of as a measure of the terrain openness as presented by a finite size threat force in a given approach tactic. The measure was calculated for both the single defensive sites (autonomous mode weapon systems), P_{LOS}, and for remoted two-party weapon systems, P'_{LOS}.

(2) Duration of Intervisibility Distributions, f(s). The duration of intervisibility distributions represents the density distribution of segment lengths, f(s), where s is the segment length during which a single target (tank trail) is continuously intervisible to a single defensive site. A similar distribution,f'(s), is used to represent the distribution of segment lengths during which a single target (tank trail) is simultaneously and continuously intervisible to both parties of a remoted weapon system.

(3) Distribution of Multiple Target Intervisibility $M(R,\Delta R,T^2,N_T,n_t)$. This distribution represents the breakout for a given number of tank trails, and range band, the distribution of opportunities (or time interval) for which "n_t" targets are visible, where $n_t = 0,1,2,3....10$ and N_T is the maximum number of trails. Thus, M(....0,10) is the fraction of the range band in which no targets are visible, M(....1,10) is the fraction that

one only is visible, M(....2,10) is the fraction that two only are visible, etc. Again, this distribution applies to both single site, M, and the remoted sites, M'.

(4) Degradation Factor for Remoted Systems, D_R. This factor is used to represent the reduction in target opportunities for the remoted weapon system as compared to those intervisibility opportunities available to the designator alone. It was computed directly from P_{LOS} for each designator site and P'_{LOS} for each of the remoted systems (designator and launch helicopter). Expressed as a percentage, it was computed as follows:

$$D_R = \frac{100 \times (P_{LOS} - P'_{LOS})}{P_{LOS}}$$

This factor was determined individually for each remoted system pair.

Section II. SIMULTANEOUS LOS ANALYSIS AND RESULTS

1. SAMPLE INTERVISIBILITY PLOTS. The intervisibility plots shown in figures II-1 through II-7 illustrate typical results obtained in the analysis. Figure II-1 is the intervisibility as seen from a single representative AH position near the ridgeline. Note the break in intervisibility as the tanks cross the creek and move through the vegetation about 3000 meters away. As they close toward the defensive site the intervisibility becomes extremely good with a tendency for frequent patches or zones of intervisibility to multiple targets.

a. A representative designator position located on the slope of the hill about 500 meters forward of the ridgeline is shown in figure II-2. The reduction in intervisibility from the previous figure is apparent, although the dominant terrain features are still obvious. Also most of the segments in the near range region are of very limited duration.

b. The simultaneous intervisibility plot that results when the designator and AH sites of the previous two figures are combined in a remoted system is shown in figure II-3. The intervisibility opportunities have been reduced to less than those shown for either of the defensive sites individually. Figures II-4 and II-5 illustrate the cases for a designator about 1500 meters forward and the simultaneous intervisibility plot with a representative AH site. The results are similar to the previous figures.

c. In figure II-6 a position behind the ridgeline is shown that represents an aerial Scout designator. When paired with the AH of figure II-1, the reduced intervisibility is shown in figure II-7.

d. The intervisibility characteristics of the terrain site are evident in each of the figures. A visual examination readily shows the "pockets," "patches," or killing zones in which several targets are intervisible. The multiple intervisibility aspects are apparent in all of the example figures, particularly for the autonomous sites along the ridgeline.

2. AREA LOS PROBABILITIES. Figure II-8 contains the results of the area LOS probability calculations for the autonomous systems and for the remoted system paired sites. For the autonomous sites in the 0 to 3000-meter range band the positions near the ridgeline representing Scout and AH popup sites have average coverages near 50 percent, or nearly twice as much as the two ground designator groups positioned forward of the ridgeline. At ranges beyond 3000 meters the coverage is reduced to about 15 percent for the Scout positions and 2 to 3 percent for the forward ground positions. Thus, the Scout positions have long range coverage about five times greater than the forward located positions. Comparison of the coverage by remoted system pairs shows similar trends; however, overall coverage is always reduced on the order of 20 to 50 percent relative to the single systems.

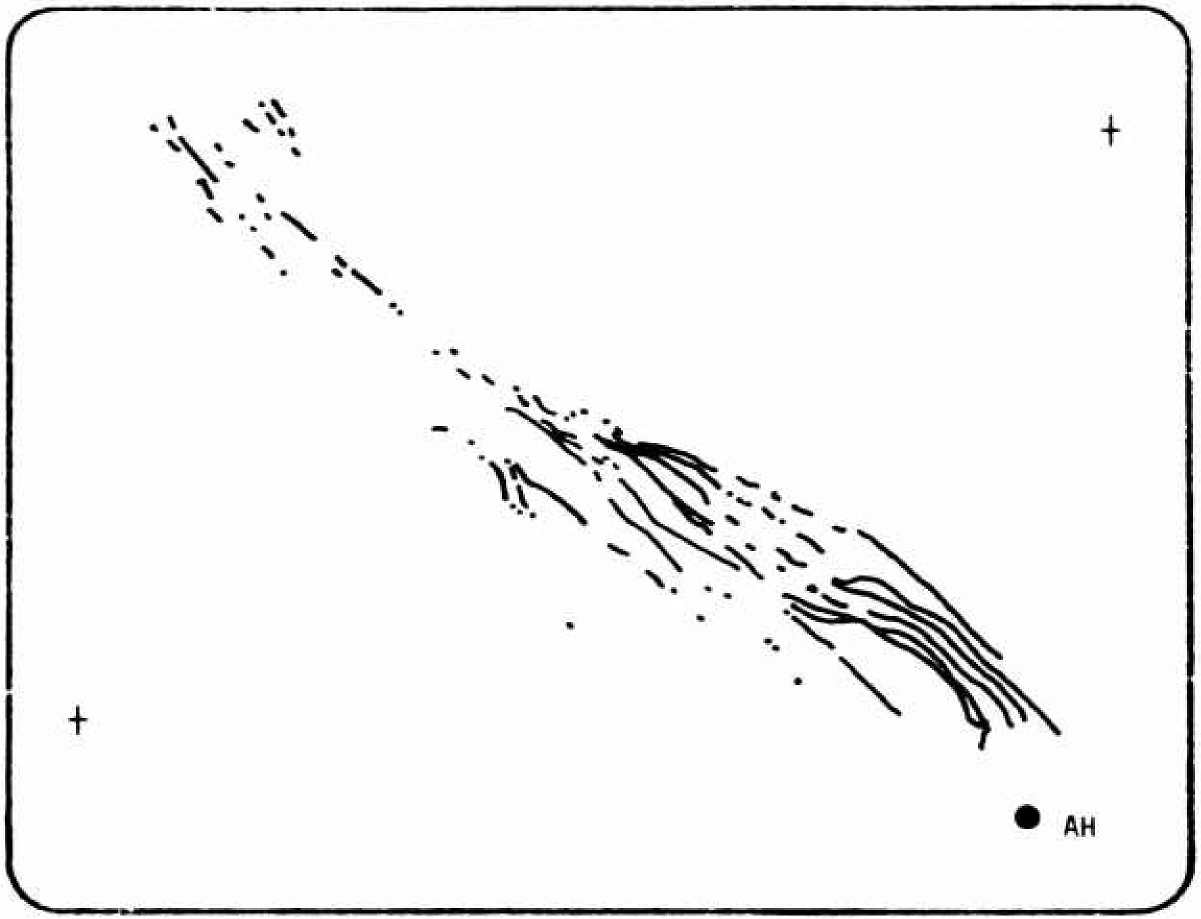


Figure II-1 - Example of AH intervisibility

Figure II-2 - Example of ground designator intervisibility when positioned 500 meters forward of the launch AH

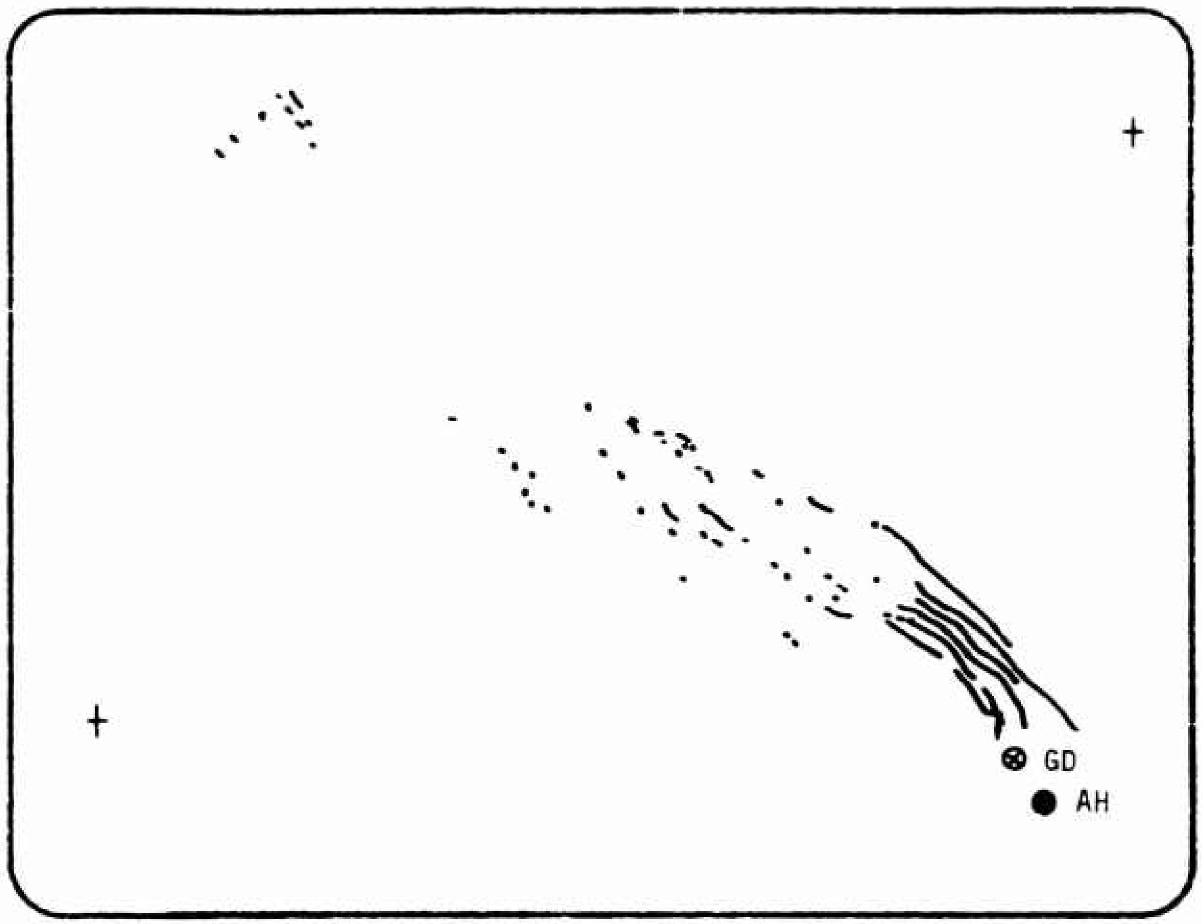


Figure II-3 - Example of the simultaneous intervisibility of a ground designator and AH (designator $\approx$ 500 meters forward)

Figure II-4 - Example of the ground designator's intervisibility when positioned $\approx$ 1200 meters forward of the launch AH

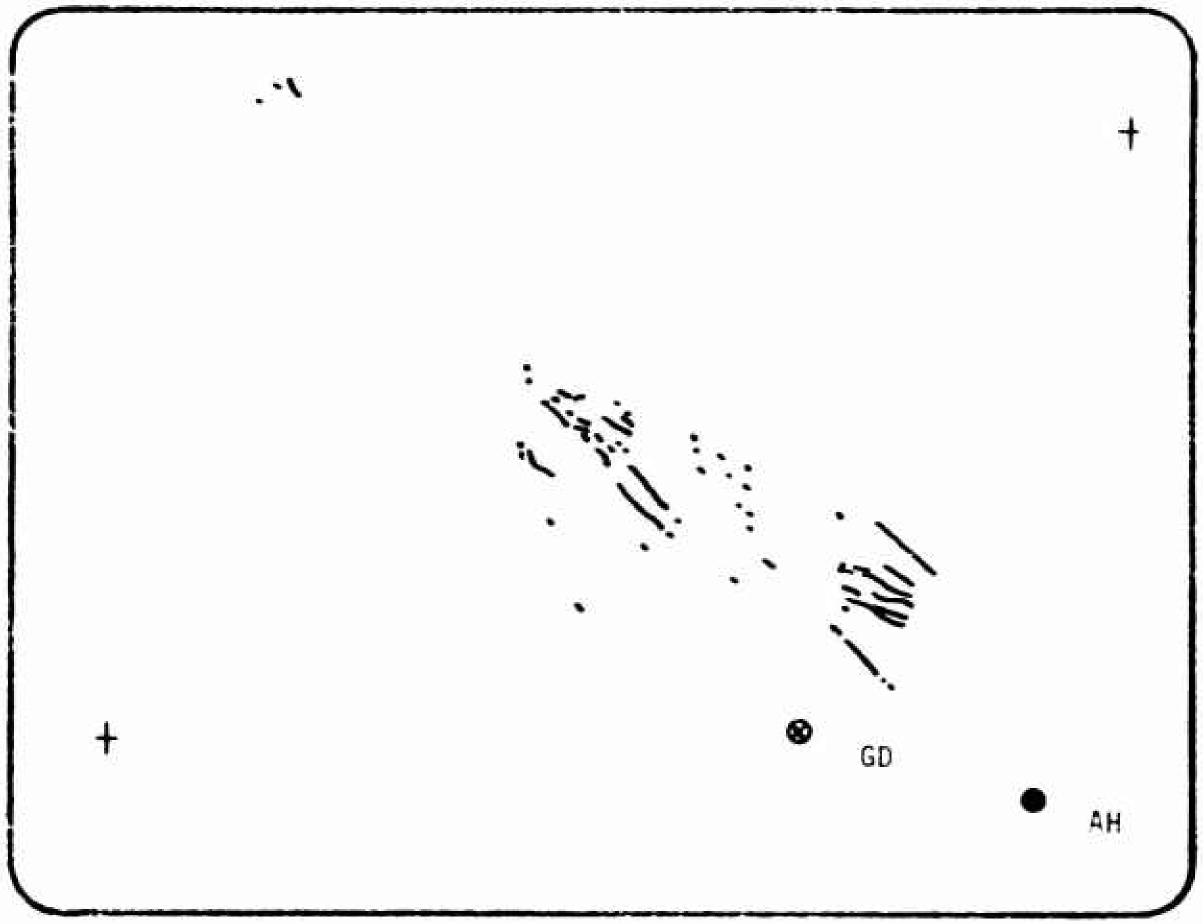


Figure II-5 - Example of the simultaneous intervisibility of a ground designator and AH (designator ≈ 1200 meters forward)

Figure II-6 - Example of Scout designator intervisibility

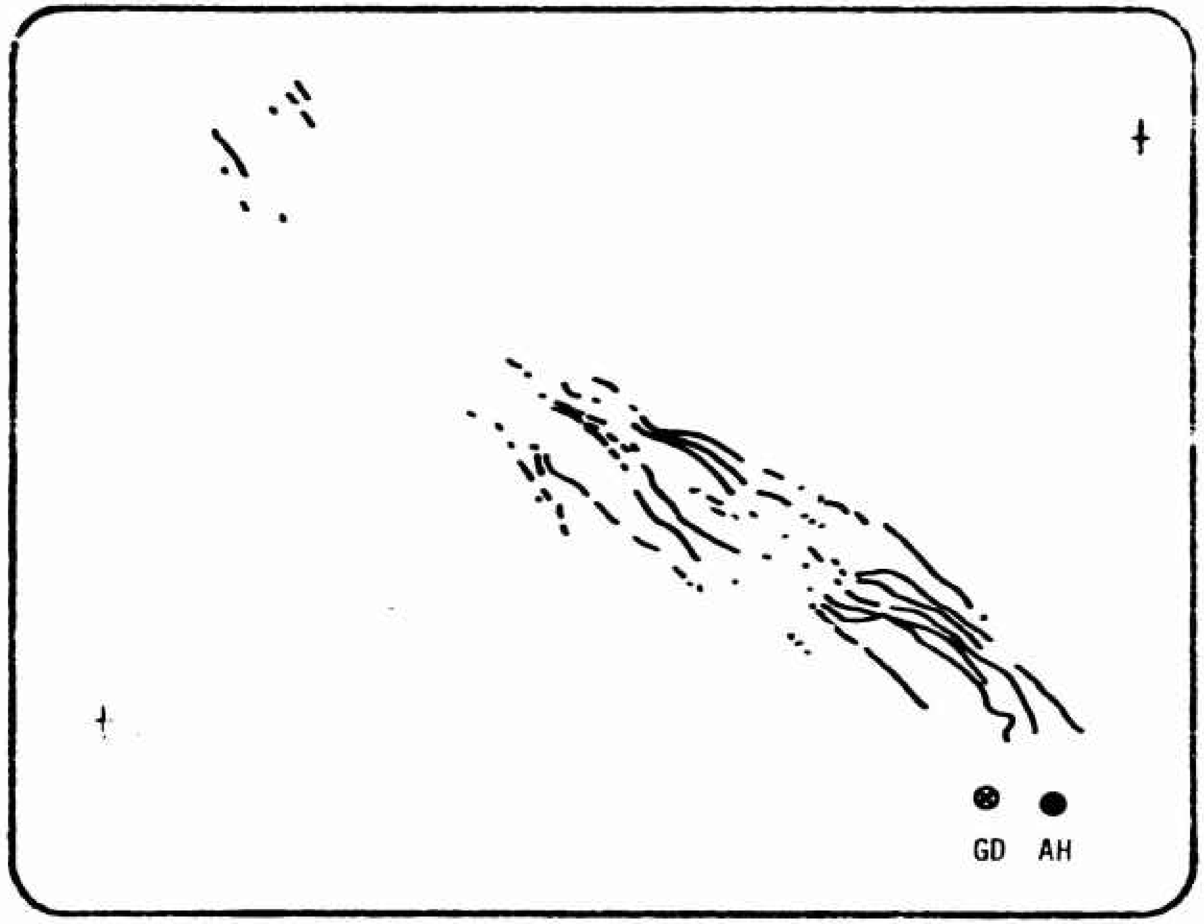


Figure II-7 - Example of the simultaneous intervisibility of a Scout designator and AH

Figure II-8 - Area LOS probabilities for autonomous, P_{LOS}, and remoted systems, P'_{LOS}

Autonomous and remoted system grouping	Sample size	0 to 3000 meter range	Beyond 3000 meter range	All ranges
Ground designators 500m forward:				
GD	9	.237	.021	.170
GD ∩ AH	126	.201	.009	.138
Ground designators 1200m forward:				
GD	13	.252	.031	.183
GD ∩ AH	182	.187	.016	.134
Scout designator (w/launch AH):				
Scout	14	.518	.149	.404
Scout ∩ AH	182	.415	.067	.305

Note: Hunter-Liggett Military Reservation, site Alpha (rapid approach)

MULTIPLE TARGET INTERVISIBILITY DENSITY DISTRIBUTION
Hunter Liggett Military Reservation Site ALPHA
(Rapid Approach)

Range	System		NUMBER OF TARGETS INTERVISIBLE, n_t										
			$n_t=0$	$n_t=1$	$n_t=2$	$n_t=3$	$n_t=4$	$n_t=5$	$n_t=6$	$n_t=7$	$n_t=8$	$n_t=9$	$n_t=10$
0-3000M RANGE	GD ~ 500 Meters Forward AH	GD	.25	.16	.17	.13	.09	.10	.08	.01	.01	-	-
		GD∩AH	.29	.19	.17	.12	.09	.09	.04	.01	-	-	-
	GD ~ 1200 Meters Forward AH	GD	.29	.19	.07	.14	.08	.06	.08	.06	.01	.01	.01
		GD∩AH	.40	.17	.12	.08	.08	.07	.04	.03	.01	-	-
	Scout with AH	SCT	.08	.07	.04	.05	.07	.15	.17	.17	.15	.04	.01
		SCT∩AH	.14	.05	.06	.09	.14	.19	.17	.11	.04	.01	-
BEYOND 3000M RANGE	GD ~ 500 Meters Forward AH	GD	.91	.04	.02	.02	.01	-	-	-	-	-	-
		GD ∩ AH	.95	.03	.01	.01	-	-	-	-	-	-	-
	GD ~1200 Meters Forward AH	GD	.82	.08	.04	.04	.02	-	-	-	-	-	-
		GD ∩ AH	.91	.05	.03	.01	-	-	-	-	-	-	-
	Scout with AH	SCT	.32	.27	.17	.13	.04	.03	.03	.01	-	-	-
		SCT∩AH	.57	.26	.13	.04	-	-	-	-	-	-	-

Figure II-9 - Distribution of multiple target intervisibility opportunities for autonomous and remoted systems

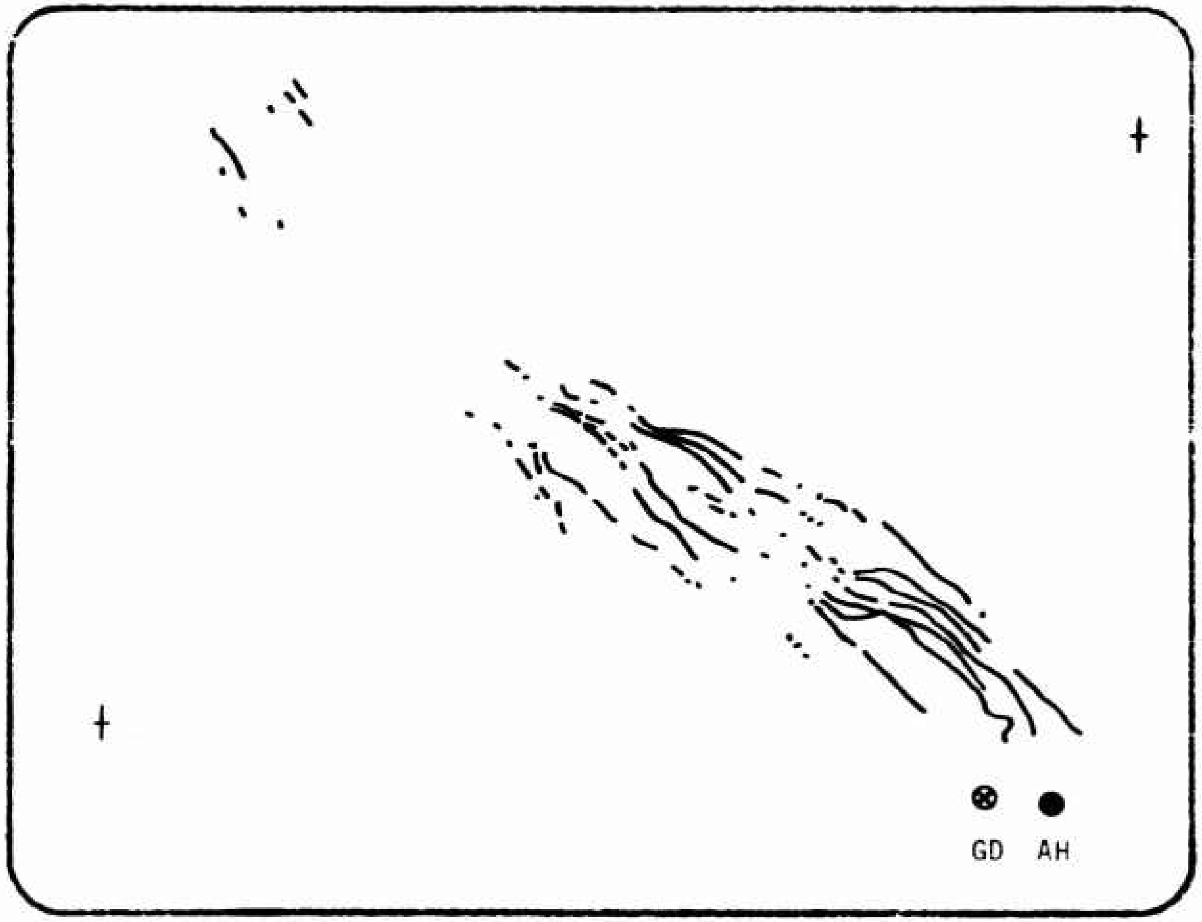


Figure II-7 - Example of the simultaneous intervisibility of a Scout designator and AH

Figure II-8 - Area LOS probabilities for autonomous, P_{LOS}, and remoted systems, P'_{LOS}

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GD ∩ AH	182	.187	.016	.134
Scout designator (w/launch AH):				
Scout	14	.518	.149	.404
Scout ∩ AH	182	.415	.067	.306

Note: Hunter-Liggett Military Reservation, site Alpha (rapid approach)

3. MULTIPLE TARGET INTERVISIBILITY. Figure II-9 contains a breakout of the frequency of occurrence of multiple target intervisibility. These results are also displayed graphically in figures II-10 and II-11 as the "percent of time" that n_t or more targets are expected to be visible. In all cases the trends shown illustrate that multiple target opportunities are reduced considerably for all the remoted systems when compared with the "opportunities" afforded the designator individually. It is also evident that for autonomous systems there are considerable multiple target opportunities, especially for the positions along the ridgeline. In fact, within the 3000-meter range band the dominant situation is for six to seven of the ten trails to be simultaneously intervisible to a Scout or AH position. When the remoted system pairs of the Scout with the AH are examined, the expected peak of the density distribution is lowered to about five tank trails. Although this is still definitely a multiple target situation, the remoted designator is now typically faced with the problem of distinguishing which one or two of the six to seven tank trails that he has intervisibility with will not be intervisible to the AH site. In effect, the problem is "how can the designator determine where his coverage is overlapped with that of the launch AH?" Including the detection and reaction aspects of target acquisition, the above problem becomes more complex and may be rephrased as "how does the designator know that the target he has acquired and selected for engagement is in LOS with the AH launch aircraft prior to an actual engagement attempt?" Thus, the remoted weapon system is presented with a terrain limitation not experienced by an autonomous system.

4. DURATION OF LOS.

a. The cumulative plots for the durations of intervisibility density functions, f(s) and f'(s), for the autonomous and the remoted weapon systems respectively are illustrated in figure II-12 for ranges from 0 to 3000 meters and in figure II-13 for ranges beyond 3000 meters. A reduction in the mean segment length, from 172 meters to 113 meters, or 34 percent, occurs at ranges less than 3000 meters. A reduction from 121 meters to 75 meters, or 38 percent, occurs at ranges beyond 3000 meters. An examination of the standard deviation, σ, for the distributions also indicates that the remoted system intervisibility distributions are much narrower. This reflects the absence of many of the longer segment lengths available to the autonomous system. The duration of a target when moving at a speed of 5 meters per second is also shown along the horizontal axis at the top of the graphs. As is evident, if total engagement times require on the order of 20 to 30 seconds, then well over 50 percent of the intervisibility opportunities would not generally permit enough time for a successful target engagement.

b. The designator of a remoted system would be expected to see segment lengths represented by the longer segment distribution; however, the AH simultaneous LOS requirement to the same target can only have the effect of reducing the usable target intervisibility length; therefore, the initiations and terminations of LOS to a given target from the designator viewpoint will usually not occur at the same time for the AH. In addition to the uncertainty the ground designator has in selecting a valid target, he will also be uncertain as to when the pairing or mutual intervisibility will be lost, or regained, even when he can constantly monitor the target.

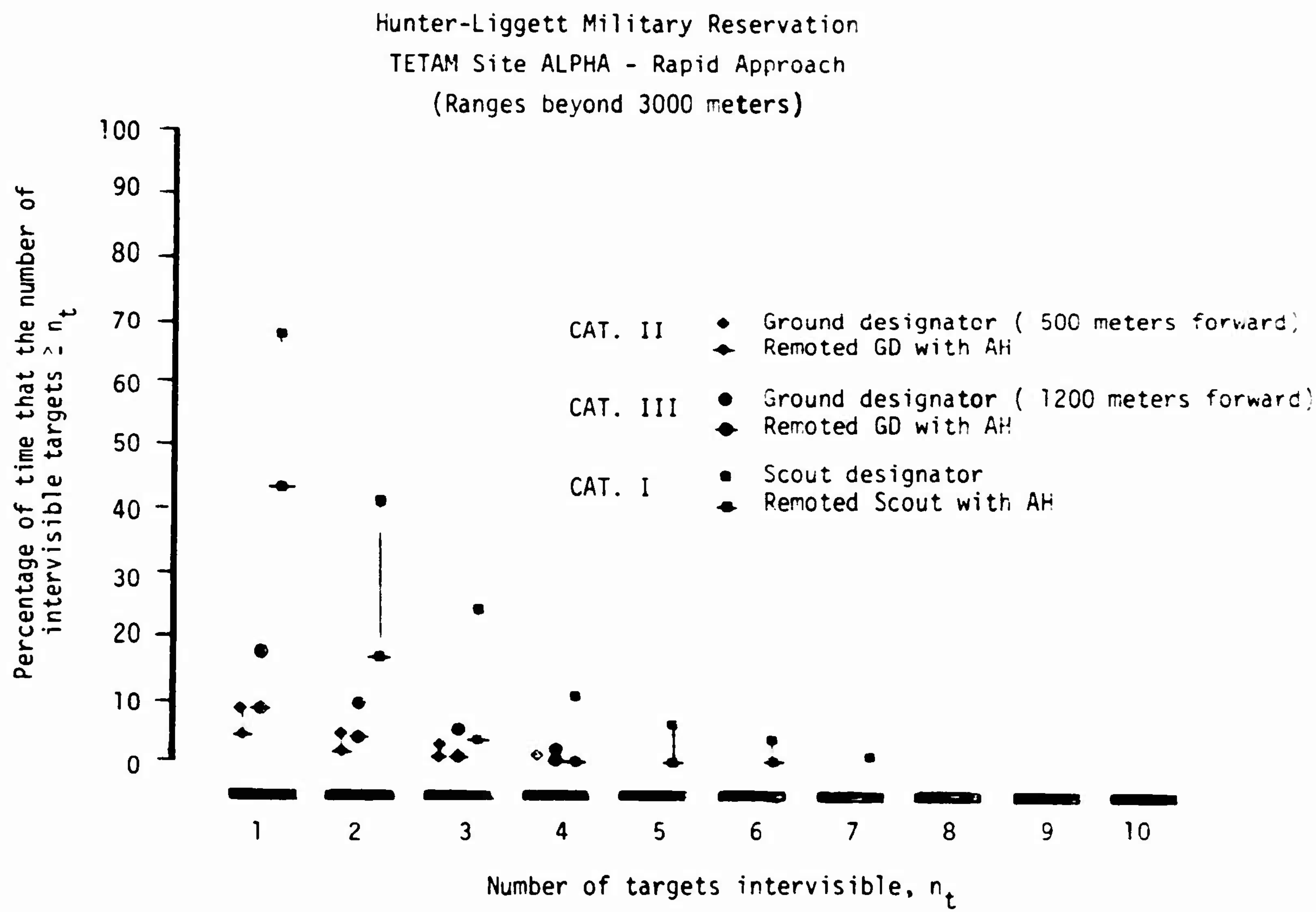

Figure II-10 - Cumulative distribution of multiple target intervisibility for autonomous, M, and remoted systems, M' (beyond 3000 meters)

Hunter-Liggett Military Reservation
TETAM Site ALPHA - Rapid Approach
(Ranges 0 - 3000 meters)

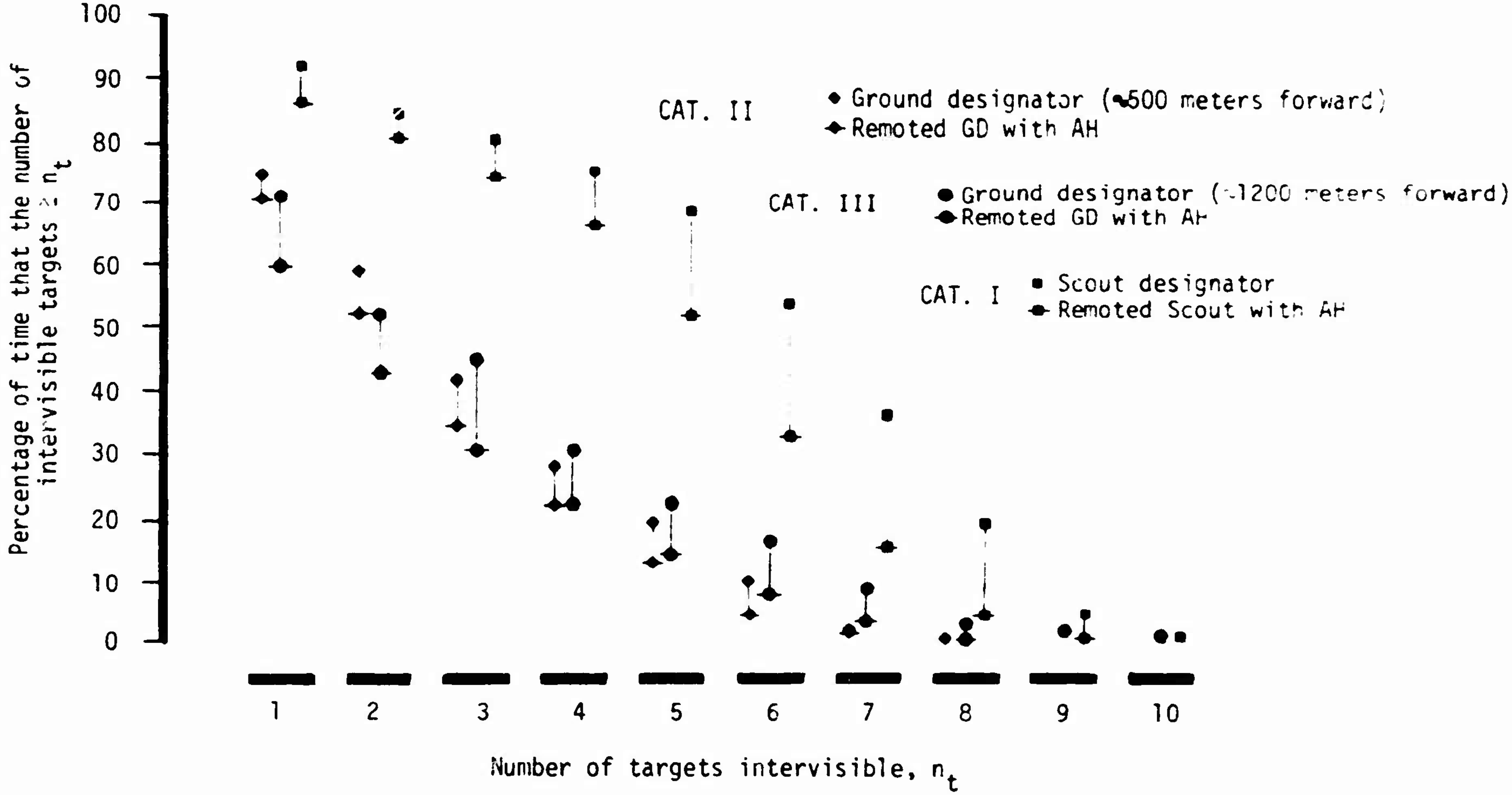

Figure II-11 - Cumulative distribution of multiple target intervisibility for autonomous, M, and remoted systems, M' (0-3000 meters)

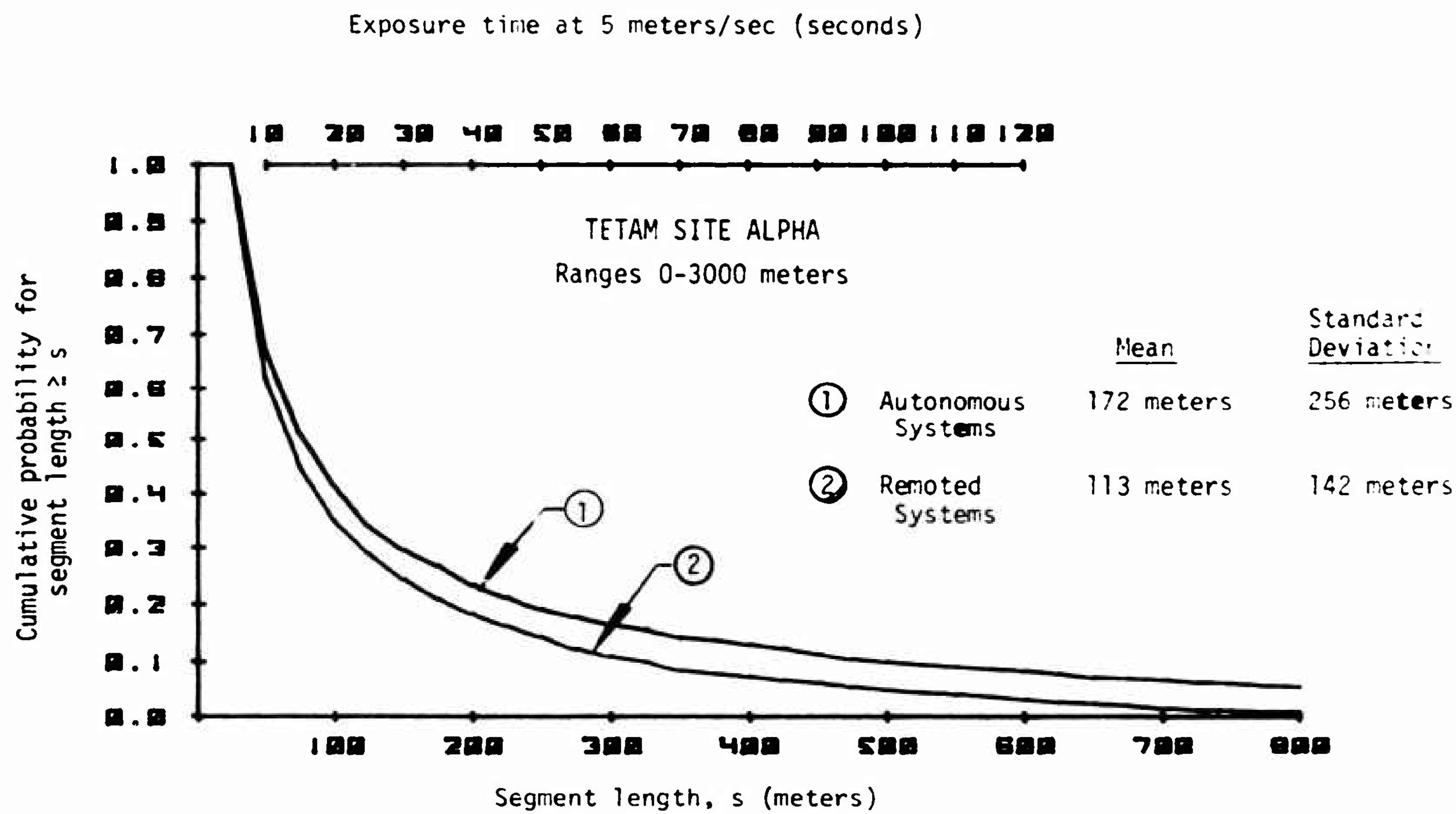

Figure II-12 - Comparisons of cumulative probability distributions for intervisible segment lengths for autonomous and remoted weapon systems (0-3000 meters)

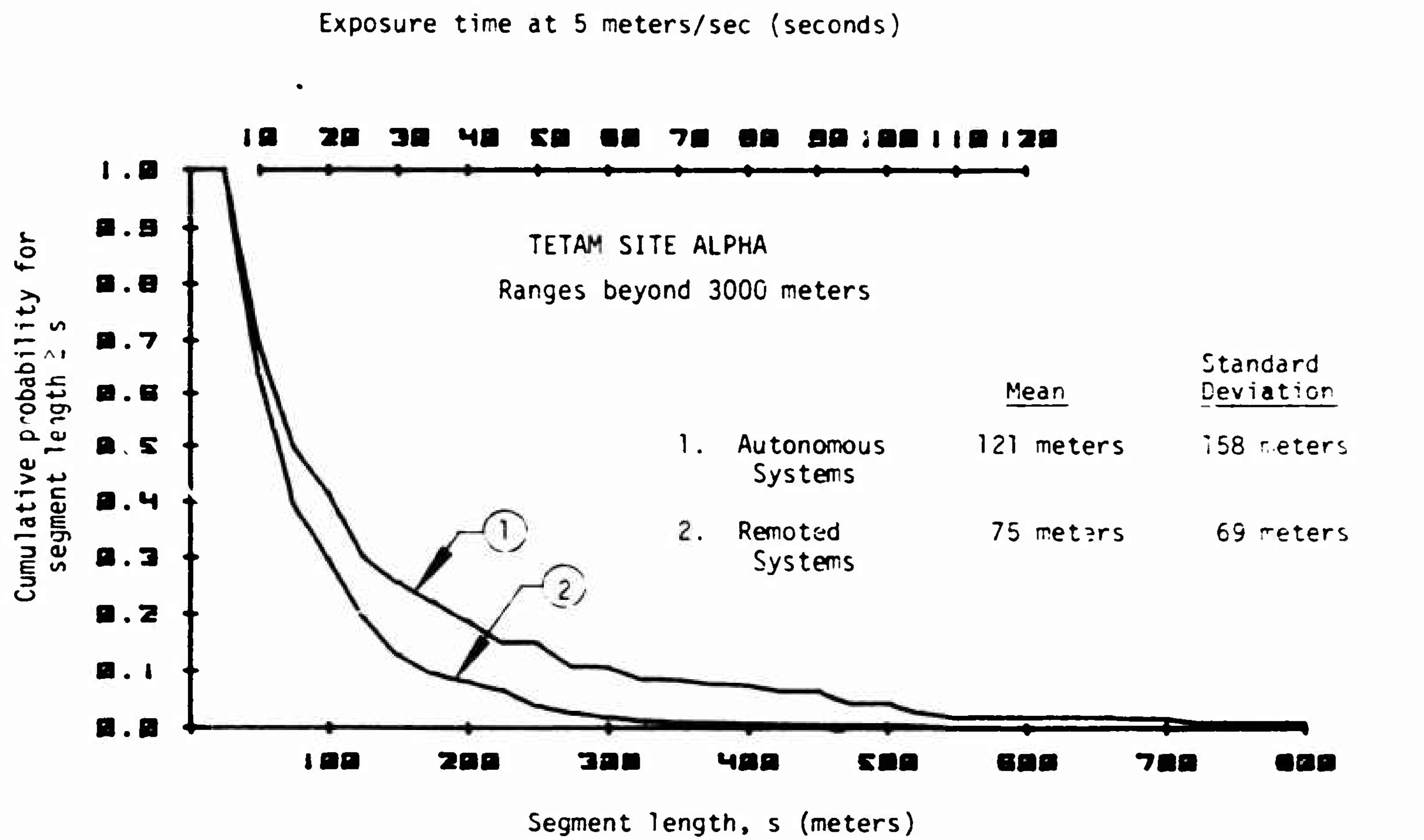

Figure II-13 - Comparisons of cumulative probability distributions for intervisible segment lengths for autonomous and remoted weapon systems (> 3000 meters)

5. REMOTED WEAPON SYSTEM TERRAIN DEGRADATION. The analysis of the data shown in the preceding paragraphs indicates that a remoted weapon system with sites located in surface or near surface terrain conditions is expected to be more severely affected by LOS limitations than would autonomous mode systems in similar positions. An estimate of this degradation relative to the single systems is shown in figure II-14 for the various range bands and designator positions. As previously defined, this degradation factor is used to represent the reduction in target opportunities for the remoted weapon system as compared to those opportunities available to the individual designator. The factor is based entirely on terrain LOS conditions.

a. The average percentage reduction in opportunities varies from 19 percent to 55 percent for the various situations considered. There appears to be a distinct range dependence with the long range band showing nearly twice the degradation of the closer ranges. Of particular interest is the group representing the Scout designator with the AH. Whereas the previous P_{LOS} and multiple intervisibility results imply a distinct advantage for the Scout positions over the forward ground designator positions, especially at the extended ranges, the degradation factor remains comparable. In fact, beyond 3000 meters the 55 percent degradation for the Scout is the most severe of any of the cases examined.

b. The average degradation factors shown in figure II-14 were computed from the individual calculations for each autonomous system and every remoted system combination. Figures II-15, II-16, and II-17 show the cumulative distribution of the degradation factors. In all cases the standard deviation is less than the mean. This implies that a degradation will almost always be present. In other words, in the data analyzed (490 sample pairs), only a very few remoted system locations can be found with negligible degradation. This is strongly indicative that the problem cannot be overcome by judicious selection of the designator location and AH pop-up or launch site. Examination of individual cases tends to imply that the instances that do show good overlap (minimal degradation) are cases where the designator position has much less than average intervisibility; that is, good coverage from the designator's viewpoint tends to increase the percent of degradation while poor coverage is equivalent to a smaller degradation.

c. In a further attempt to understand the nature of the degradation effects, the scatter diagrams of figures II-18 through II-23 were plotted. These figures are plots of each of the individual degradation factors displayed along the vertical, and the separation between the designator and launch AH in the remoted system pair is shown along the horizontal axis. Figures II-18 and II-19 illustrate the Scout designator and AH pairs at range bands of 0 to 3000 meters and greater than 3000 meters respectively. In both cases, there appears a definite trend toward increased separation distance. The scatter of the points in the vertical direction is rather restricted as mentioned before, and the observation that there are extremely few instances that have little degradation is reinforced.

EXPECTED REMOTED SYSTEM TERRAIN INTERVISIBILITY DEGRADATION

DESIGNATOR CATEGORY	REMOTED SYSTEM DESIGNATOR LOCATION	RANGE BAND	
		0-3000 Meters	BEYOND 3000 Meters
CATEGORY I	SCOUTS POSITIONS (Same Ranges as AH)	20%	55%
CATEGORY II	GROUND POSITIONS (500 Meters Forward AH)	19%	46%
CATEGORY III	GROUND POSITIONS (1200 Meters Forward AH)	33%	47%

Figure II-14 - Remoted weapon system average terrain degradation factors

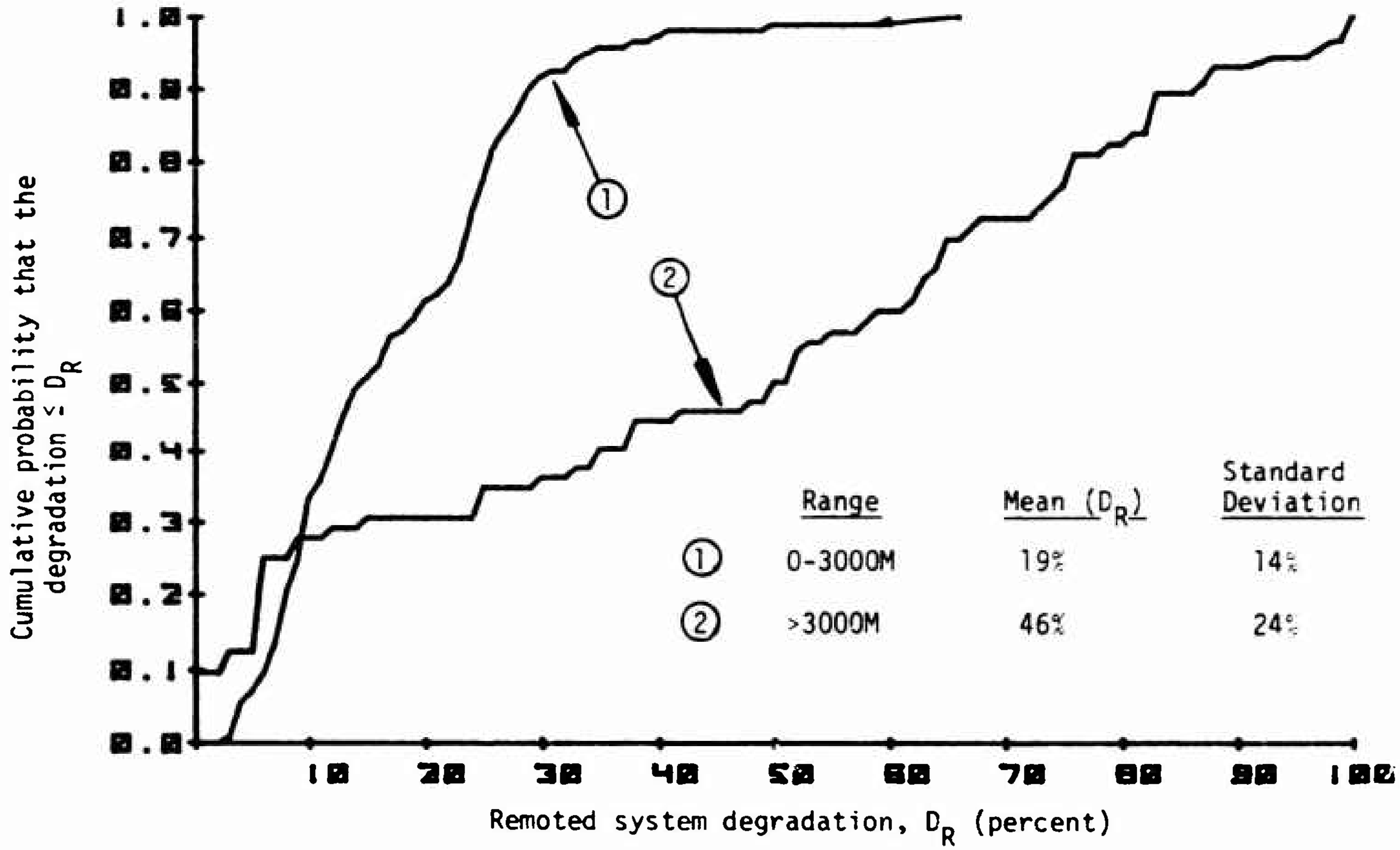

Figure II-15 - Cumulative distribution of degradation factors for the close (500 meters) ground designator positions

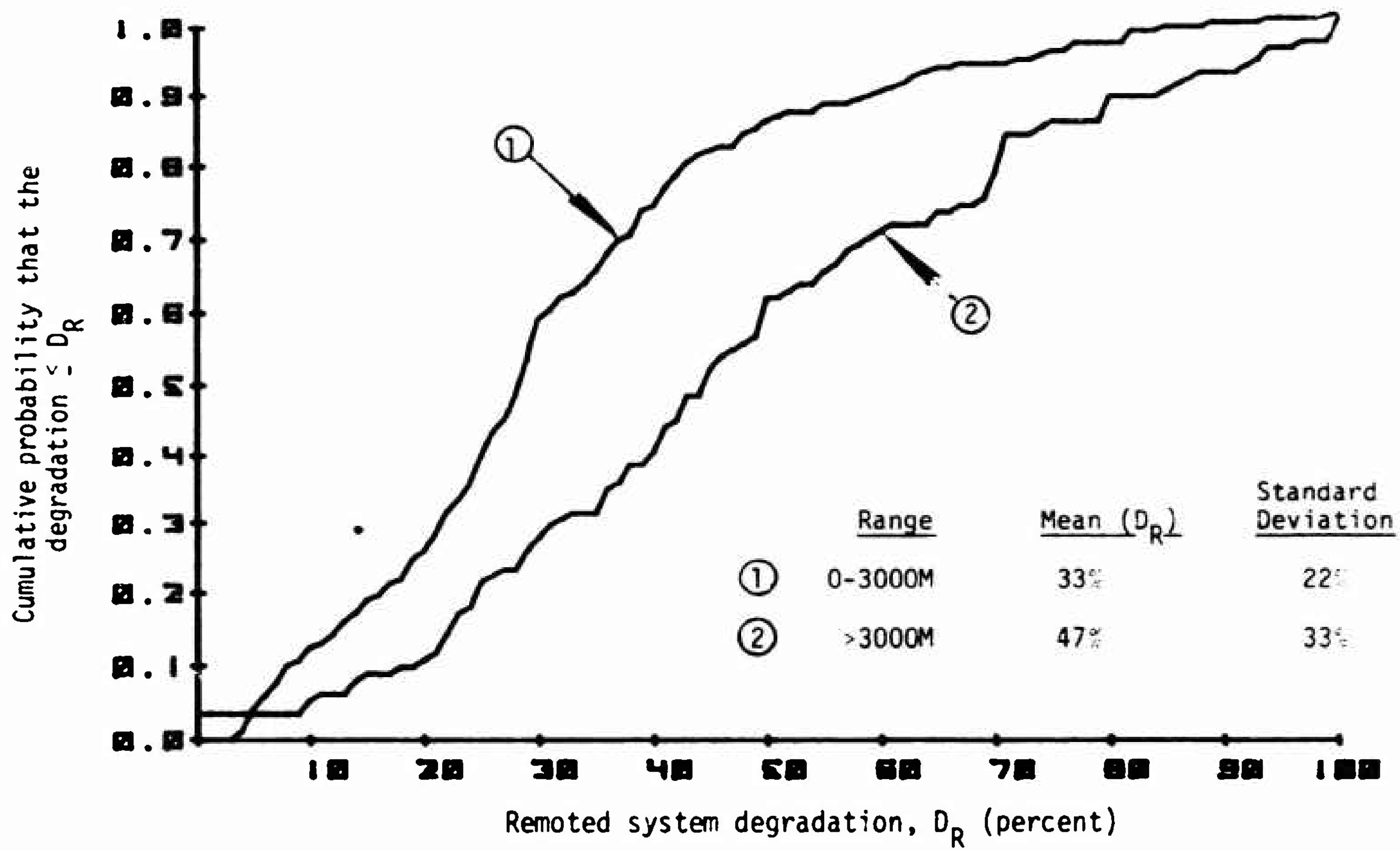

Figure II-16 - Cumulative distribution of degradation factor for the far (1200 meters) ground designator positions

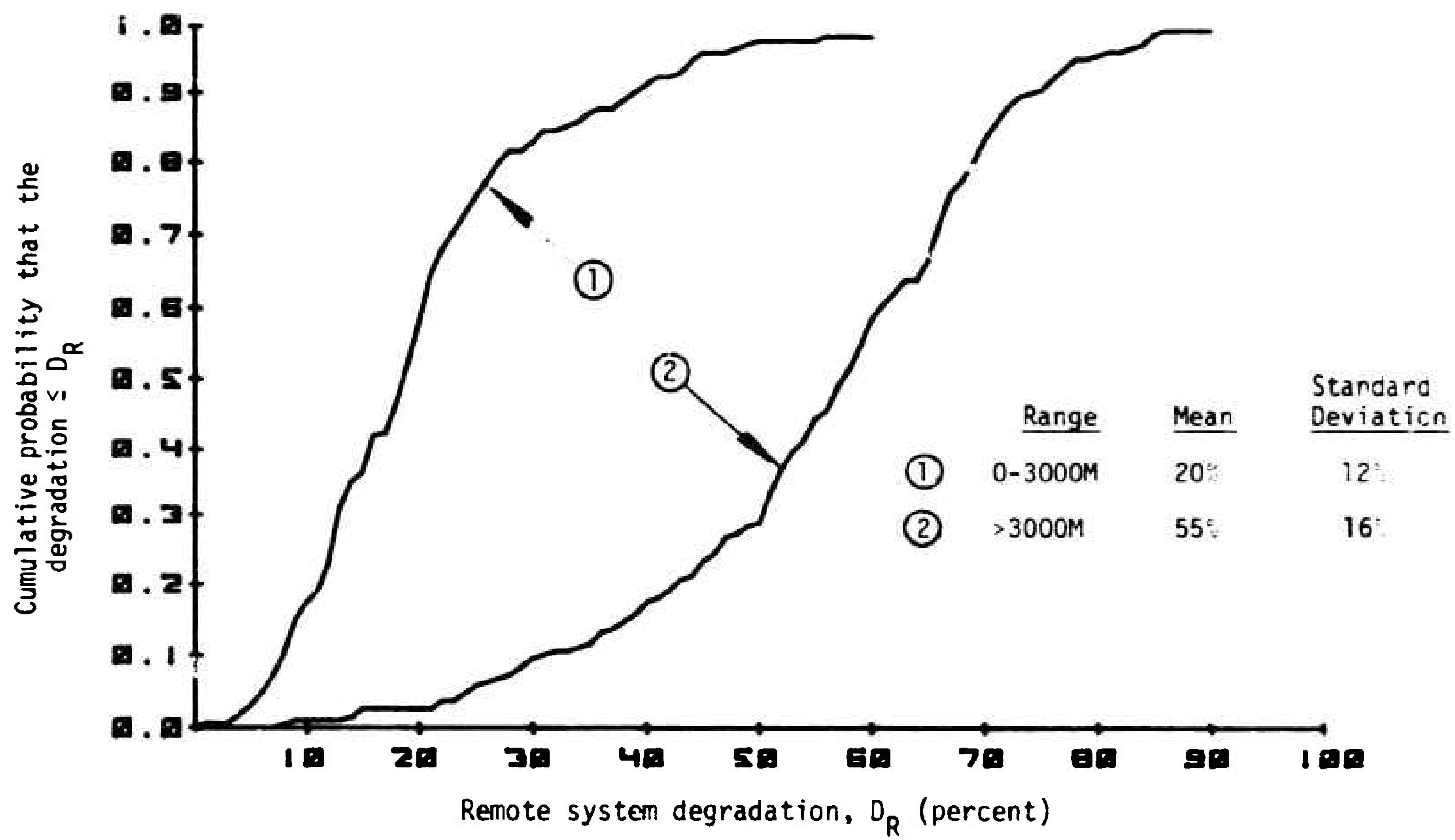

Figure II-17 - Cumulative distribution of degradation factors for the Scout designator positions

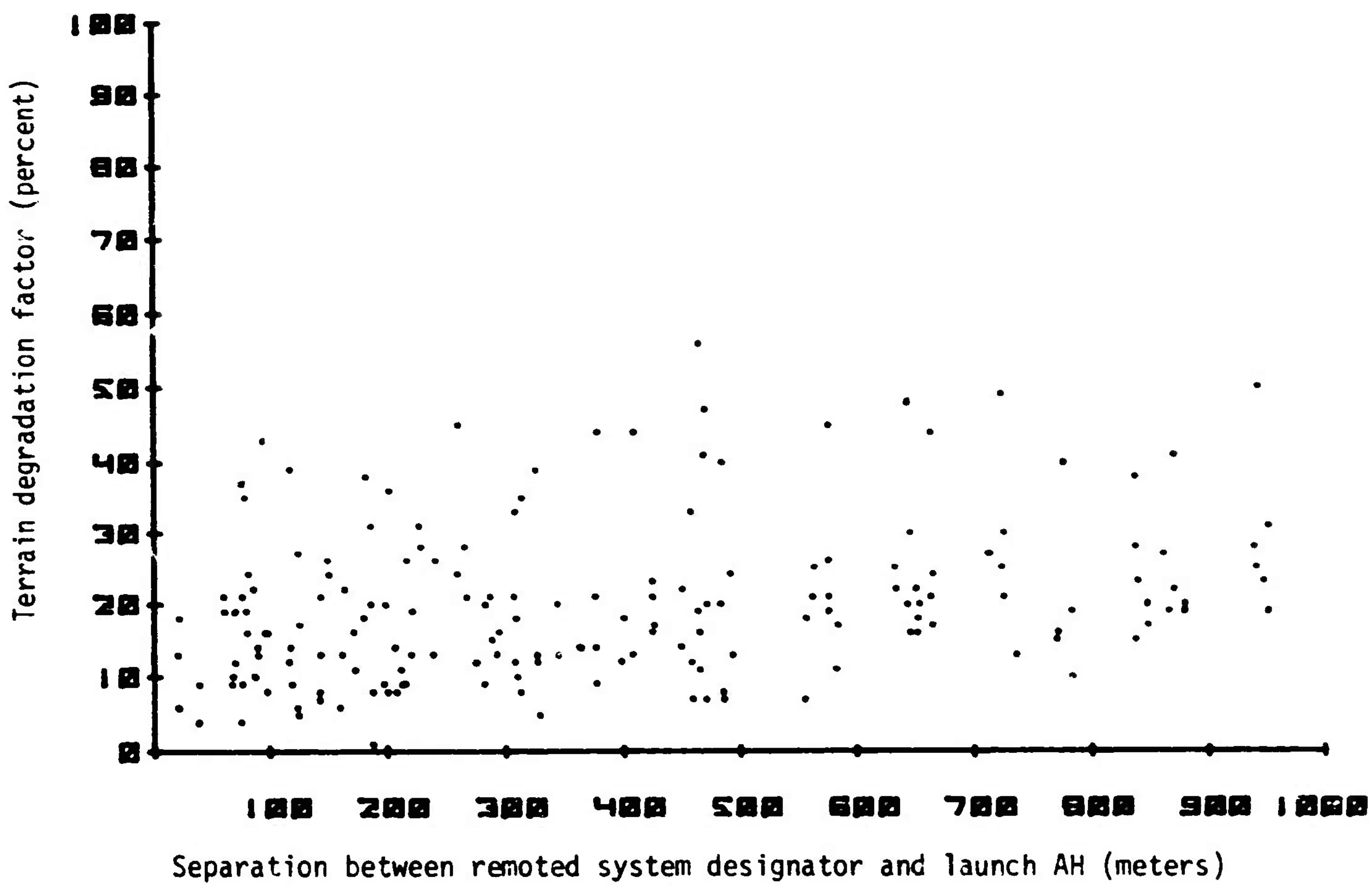

Figure II-18 - Scatter diagram of degradation factors versus remote system separation distance for Scout and AH pairs (0-3000 meter range bands)

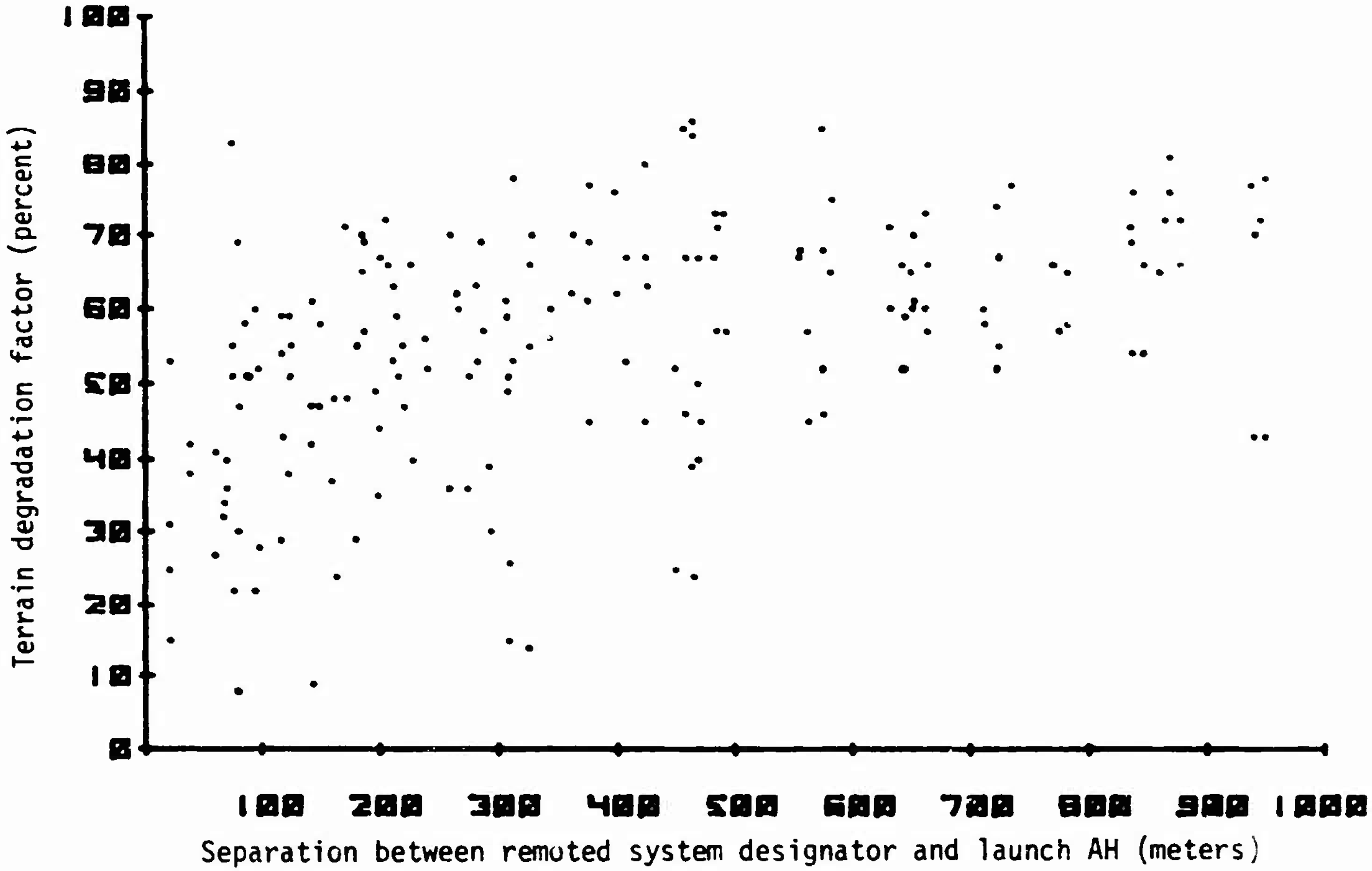

Figure II-19 - Scatter diagram of degradation factors versus remote system separation distance for Scout and AH pairs (>3000 meters range bands)

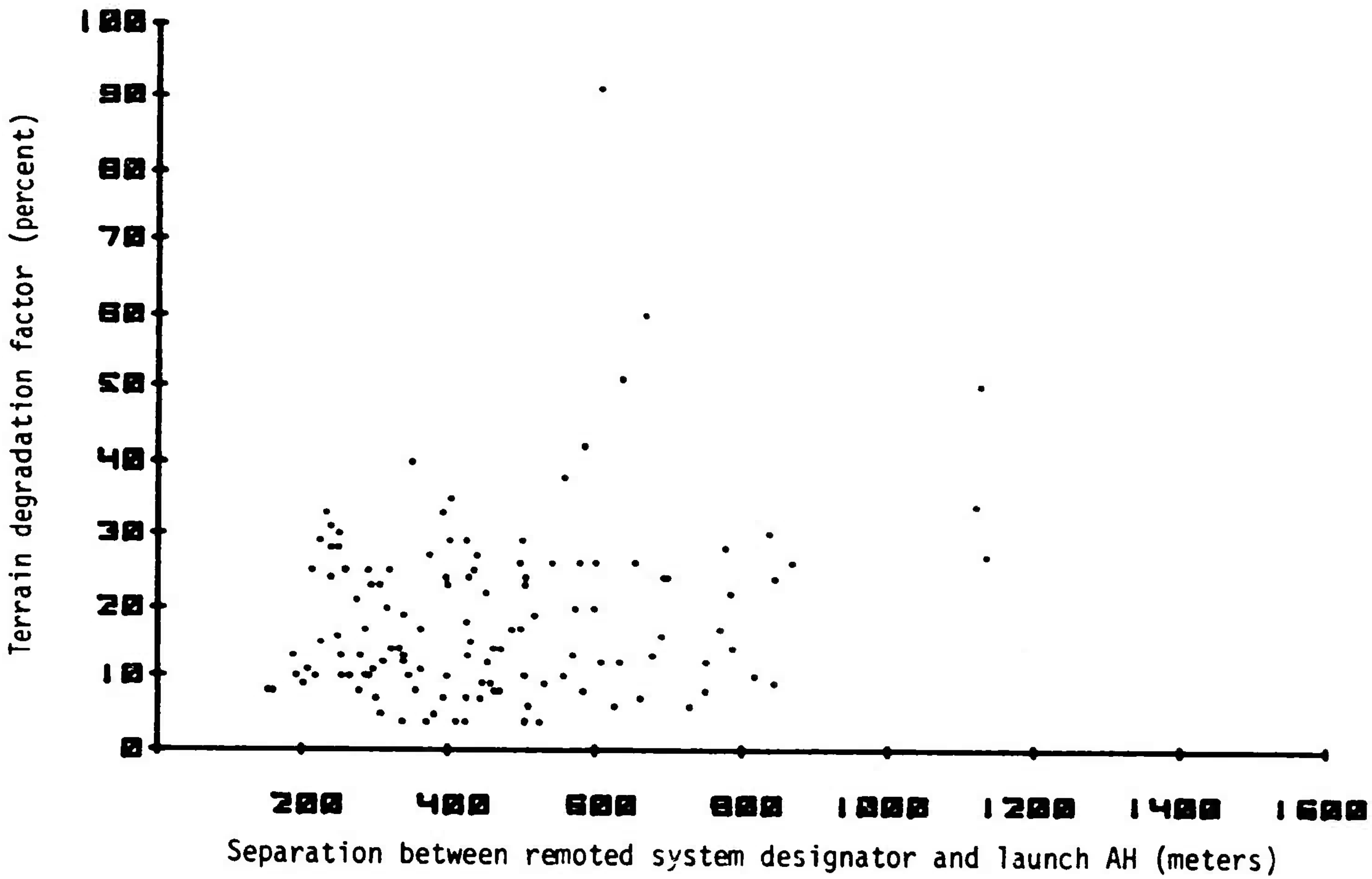

Figure II-20 - Scatter diagram of degradation factors versus remote system separation distance for 500 meter forward ground designator and AH pairs (0-3000 meters range band)

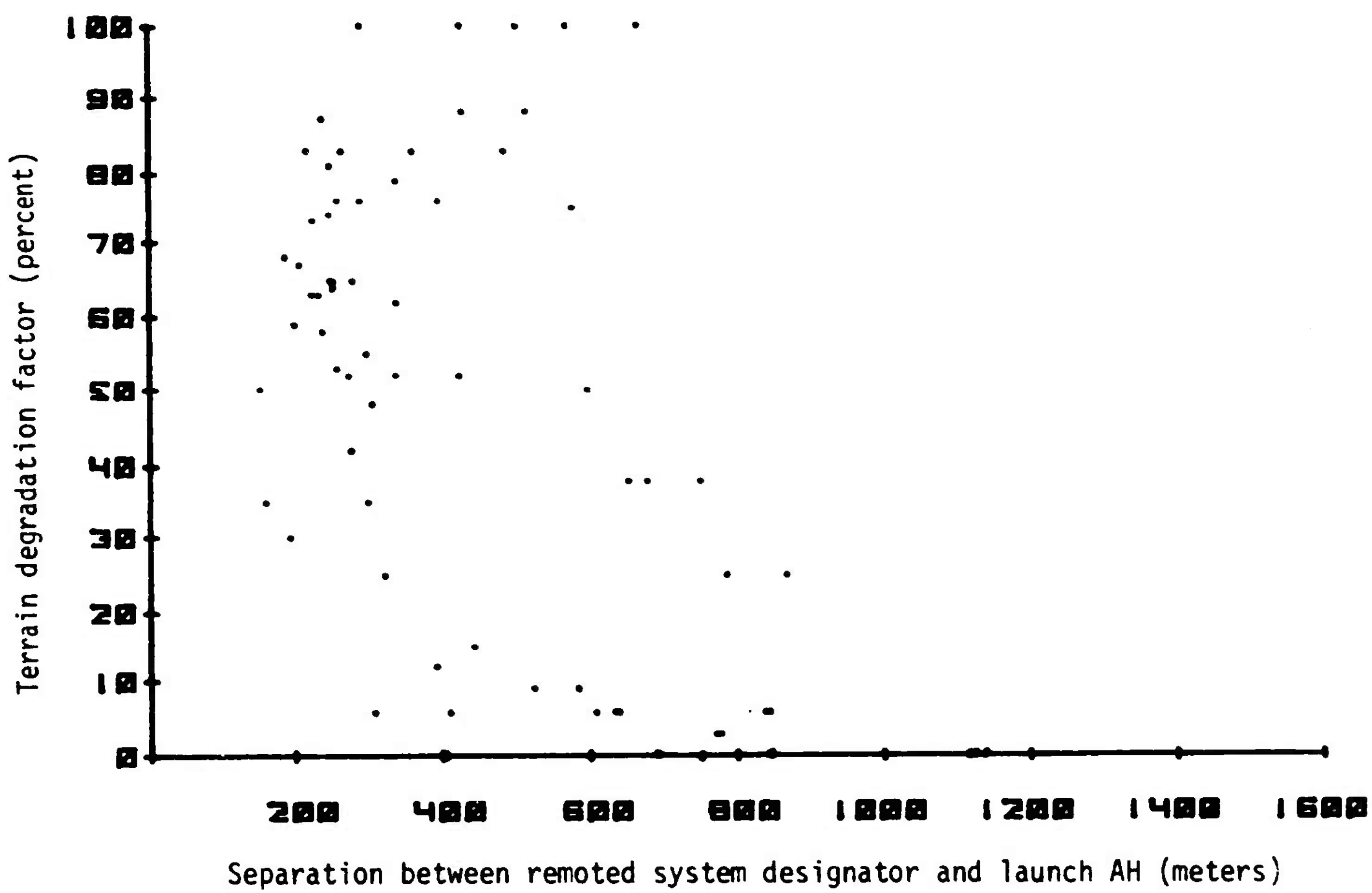

Figure II-21 - Scatter diagram of degradation factors versus remote system separation distance for 500 meter forward ground designators and AH pairs (>3000 meters range band)

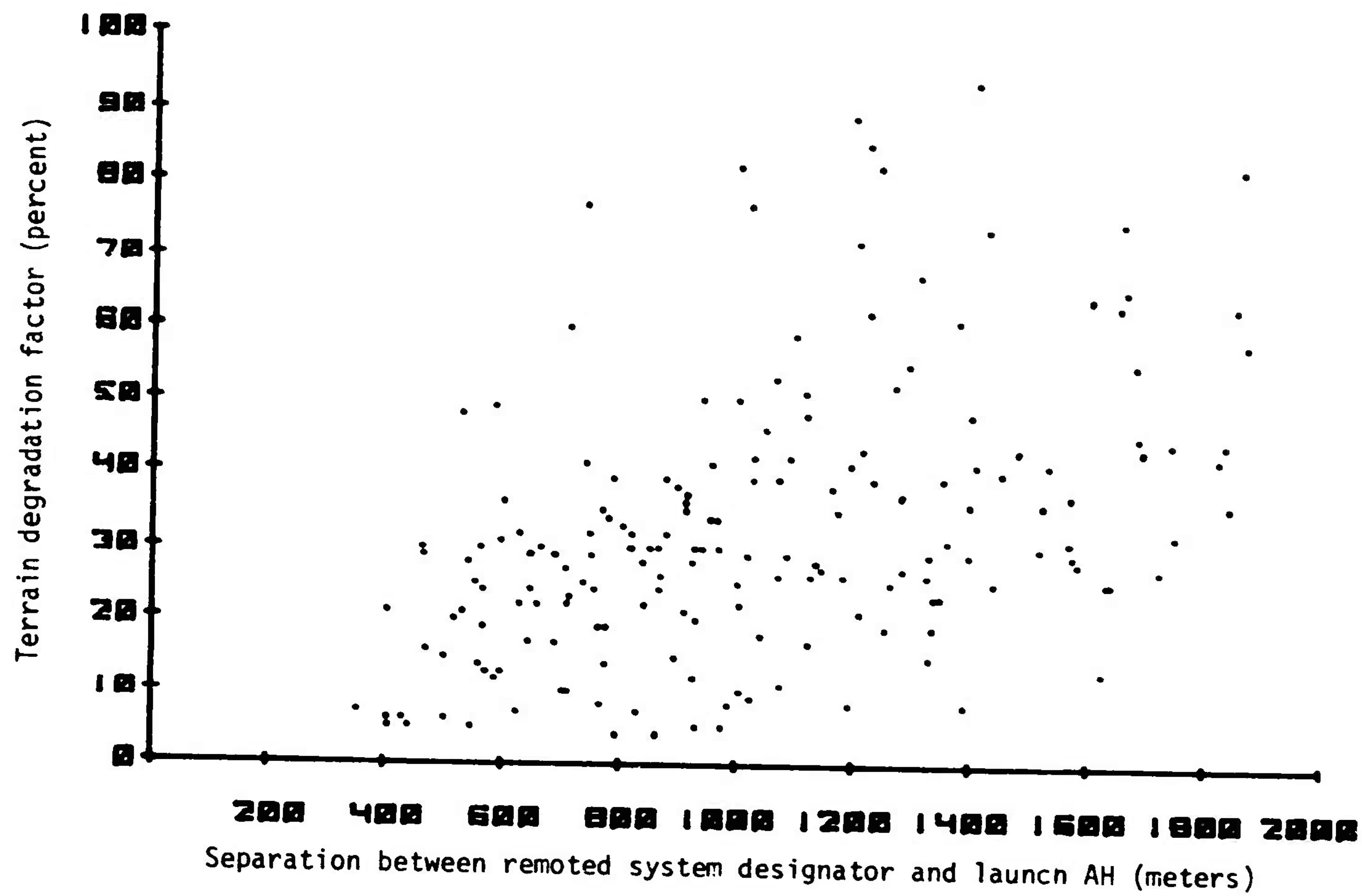

Figure II-22 - Scatter diagram of degradation factors versus remote system separation distance for 1200 meter forward ground designators and AH pairs (0-3000 meters range bands)

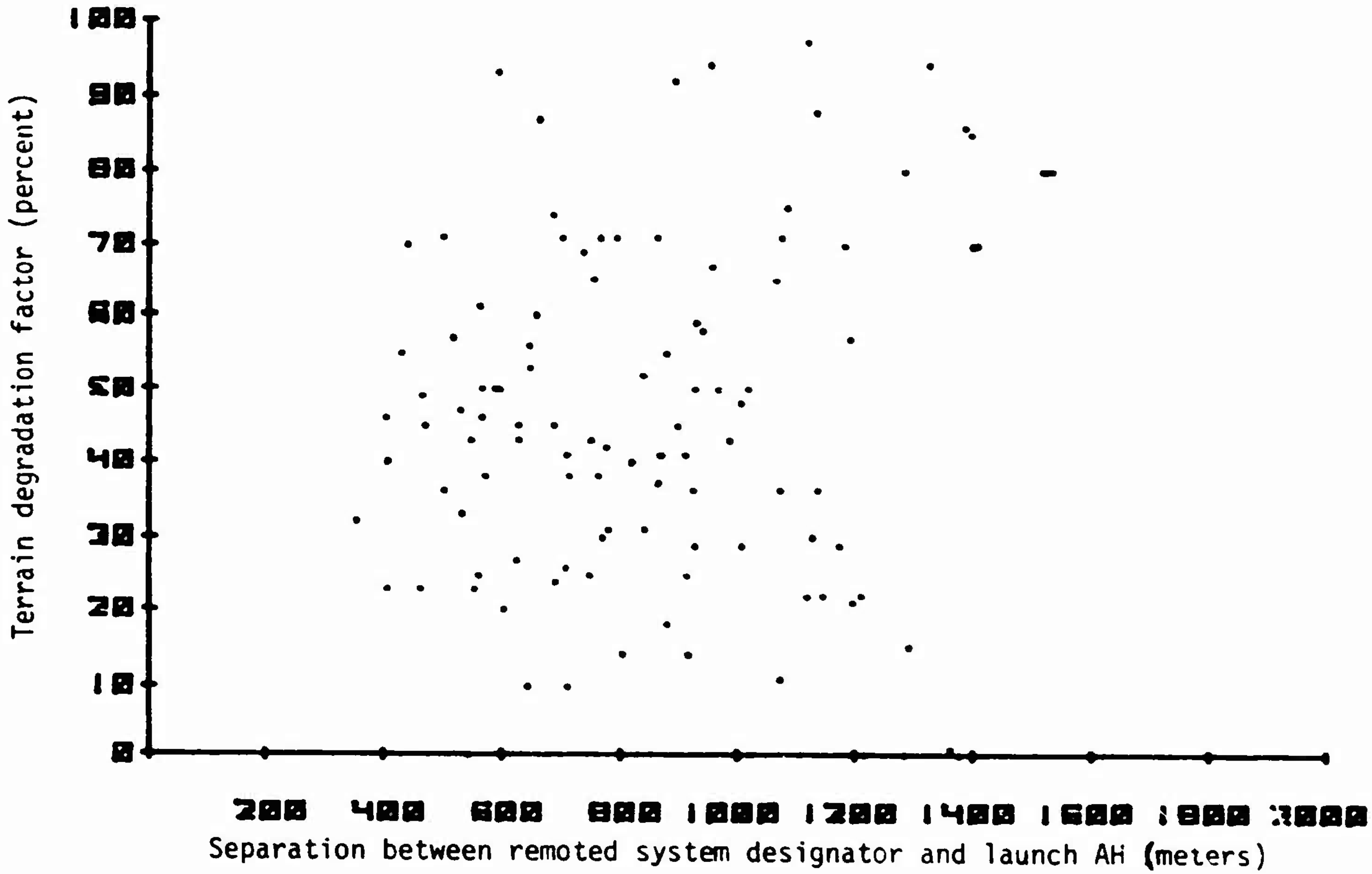

Figure II-23 - Scatter diagram of degradation factor versus remote system separation distance for 1200 meter forward ground designators and AH pairs (>3000 meters range bands)

The forward ground positions do not show any definite range dependent trends. These sites, however, are generally positioned forward of the launch sites and have a reduced lateral spread, thus possibly masking any separation versus degradation trends. Also, the dominant effect of the separation is expected where the separation is perpendicular to the general direction of the target area.

Section III. RESULTS AND OTHER CONSIDERATIONS

1. SUMMARIZED RESULTS. The LOS terrain effects on a remoted weapon system that requires dual line-of-sight to a potential target, as examined in the specific terrain of HLMR TETAM site ALPHA, indicate a significant reduction in target intervisibility. Specific aspects of the reduction are as follows:

a. The expected reduction in target intervisibility opportunities (i.e., coverage) for a remoted system that requires direct LOS over that expected for an autonomous system is in the order of 20 to 50 percent.

b. The area LOS probabilities at extended ranges are quite small, ranging from .02 to .15 for autonomous mode systems, and .01 to .07 for the remoted systems.

c. The duration of target intervisibility for a remoted system is generally reduced about 30 percent over that expected for an autonomous system.

d. Multiple target intervisibility opportunities are significantly reduced for a remoted system.

2. OTHER CONSIDERATIONS.

a. As previously noted, the above analysis was restricted to the HLMR site ALPHA terrain. The results may be different for other terrains; however, limited examination of such terrain sites as the TETAM European Fulda sites and HLMR site BRAVO tend to indicate that the above results are by no means worst case.

b. The real significance of the reduction in coverage expected for a remoted system cannot be adequately addressed without a complete examination of the operational characteristics and performance limitations of the actual hardware of the weapon system and crew; however, the desirable features of any remoted system on the ground or near surface must be such that it can offset this loss of coverage. Thus, the remoted system should be very responsive and possess a high rate of fire.

c. The vulnerability aspect of a remoted system as represented entirely from the target intervisibility viewpoint tends to show <u>increased coverage</u> by the threat weapon; that is, the threat coverage of either party of the remoted system is represented by the "union" of S_1 and S_2, figure I-2. Therefore, if both parties in a remoted system are critical to the system's performance, the remoted system presents a larger effective target to the threat. Again, the remoted system may be able to offset this by reduced signature and/or reduced response and exposure times.

d. To summarize the implications of the above, the results emphasize that the advantages of a remoted system over an autonomous system must accrue by virtue of a higher rate of fire capability. Furthermore, the remoted concept also relies on the supposition that the same targets generally appear sequentially as "clusters" such that adequate battlefield coverage can be obtained with a lower density of friendly positions. The above results and discussion lead one to conclude that comparisons between remoted systems and autonomous systems are expected to contain complex terrain dependencies that require a much more sophisticated examination of terrain than generally required for conceptually similar type weapons.

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